Forest Research and Management Demonstration Area: Thunder Bay Spacing Trial

Ontario

Ministry of Natural Resources

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Minister

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THUNDER BAY SPACING TRIAL

Importance of Spacing

The amount of growing space available to a tree influences the amount of wood produced. Trees with greater available growing space will produce more wood. However, increased numbers of trees per unit area will produce more wood in a shorter time than fewer larger trees. This is because the available resources, such as light, water, and nutrients are being used more thoroughly. Spacing also affects the quality of the wood. Wide spacings result in more and larger branches which in turn result in knotty lumber.

How far apart should trees be planted? This depends on two main factors: 1) the species, because various species have different ecological requirements and different growth habits, and 2) the intended end use of the trees. As an example, pulpwood can be produced by harvesting small trees but dimension lumber is produced most efficiently from larger trees.

The amount of growing space initially allocated to each tree pre-determines future management options and, to a great extent, the cost involved in producing the wood. For example, increasing the number of trees planted in an area will result in greater initial investment. If dimension lumber is the desired product, some of the closely spaced trees will have to be thinned (some will be removed to leave the remaining trees more growing space). This further increases financial investment in the crop.

The forester must take all of these factors into consideration when deciding how far apart to plant his trees. To illustrate this a trial was established to document the growth response of several boreal forest species to different densities. This information is very important for forest managers in northern Ontario.

History and Objectives

The Thunder Bay spacing trial was established in 1951 by the Department of Lands and Forests, now the Ontario Ministry of Natural Resources, on the Thunder Bay Forest Station. It included black spruce, white spruce, red pine and white pine planted at three spacings: 1.8 x 1.8 m (2900 trees per ha), 2.7 x 2.7 m (1300 trees per ha) and 3.6 x 3.6 m (730 trees per ha) (one ha equals 2.47 acres).

The objective of the trial was to examine the effect of planting density (tree spacing) on stocking (number of trees per ha) over time. The trial now also provides a unique opportunity to study the growth response and productivity of the species at different densities.

In 1988 a self-guiding interpretative trail was established to enable foresters and the public to view the effects of spacing on forest stands, to compare the growth of common species on the same site and to

present the potential for fibre production from plantations.

The layout of the spacing trial is shown in Figure 1. Within each of the three spacing methods, three blocks of each species were planted, with the exception of black spruce and white spruce in the 1.8 x 1.8 m spacing. Jack pine was planted at 1.8 x 1.8 m as a buffer around the trial.

One of the black spruce blocks in the 1.8 m spacing failed and was replanted to red pine in 1956. In 1965 all of the white pine was removed because of white pine weevil and blister rust damage. The empty blocks are now used for research trials by the Ontario Tree Improvement and Forest Biomass Institute.

The trees in the plantation have not been tended (weeded, thinned or pruned). They were measured in 1967, 1976 (subsample only), 1983 and 1988 to provide information on the growth response of the three species at different spacing and changing densities over time.

Species

The three species remaining in the trial are common northern Ontario forest species. Black spruce is Ontario's most important commercial tree species and is used mainly for pulp. Its wood consists of long fibres which are ideal for high quality paper. White spruce is used for both pulp and sawlogs. Red pine comprises a minor component of the boreal forest. It grows faster than the spruces and is used mainly for poles and dimension lumber, although it can also be used for pulp and paper.

Planting Site

The spacing trial is located on a glaciolacustrine plain (glacial lake bottom) with a flat to gently rolling landscape. The soils are fine sandy loams over very fine sandy clay loams at >160 cm. The soil moisture regime is fresh and drainage is rapid.

The site ranges from good to excellent for the species involved (site index is the height (m) of the dominant trees at age 50):

Black Spruce -	Site Class 1a	(Site Index 18)
White Spruce -	Site Class 2	(Site Index 18)
Red Pine	- Site Class 1	(Site Index 21)

Growth and Yield

The spacing at which trees are grown has a significant effect on the productivity of the individual tree as well as the stand. Spacing influences the size of tree crowns in terms of length, width, branch thickness and amount of foliage. The crown of a tree refers its branches and foliage. The size of the tree crown, in turn, influences the productive potential of the

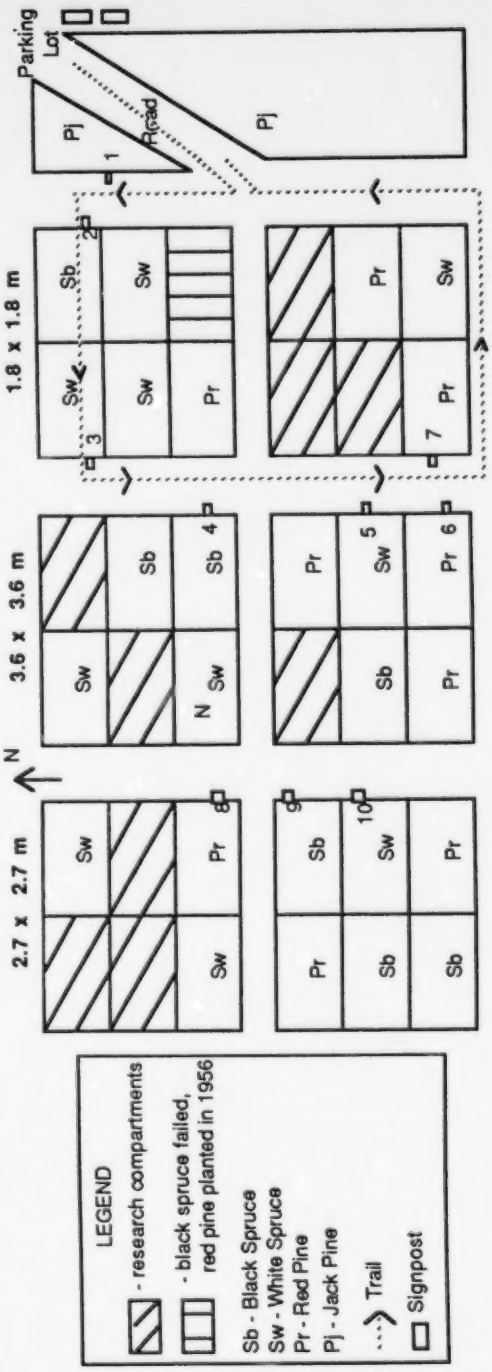

Figure 1. Layout of the Thunder Bay Spacing Trial and location of self-guiding trail.

individual tree and the stand as a whole. Within a stand, tree crowns expand until they run out of space and the canopy (all the crowns) closes. The lower branches then begin to die from mutual shading and crown width is limited by abrasion. Self- pruning of dead branches is evident, especially in red pine.

At wider spacings, larger crowns usually support more foliage. The increased foliage area results in more wood being produced by the individual tree. Unfortunately, wider spacing also results in the persistence of more and thicker living branches. Resulting knots and defects of the stem reduce the value of sawlogs. Pruning branches periodically will reduce this problem.

The relative size of the crowns and the amount of overlap for the three species at the 1.8 and 3.6 m spacings is shown in Figure 2. The crowns are much larger at the wider spacings in terms of length and width.

Spacing has no significant influence on height growth of individual species (Figure 3) but height between species does differ. Red pine grows much faster on this site than either white or black spruce. Diameter (the distance through the stem at a height of 1.3 m) growth increases with increasing spacing for all three species (Figure 4).

Full utilization of the site (the point beyond which trees begin to die from competition) occurs earliest at close spacings. Thus, productivity is greater than at wide spacings (Figure 5) at younger ages. That is, more wood is produced per unit area whereas at wide spacings, the productivity of the individual tree is maximized (Figure 6).

Since full site occupancy occurs earlier at close spacings, competition between trees also commences earlier. This results in mortality through natural suppression in the spruces and a slowing of growth in the pines. The per cent survival and number of stems per ha for the three species at all three spacings over time are shown in Table 1. The per cent survival in 1967 (age 16) indicates initial mortality which does not differ significantly between species or spacings (except for white spruce planted at 2.7 m where high initial mortality was attributed to flooding). Mortality caused by competition is apparent by 1988 in both the black and white spruce planted at 1.8 m. This type of mortality is not apparent in the 2.7 or 3.6 m spacings. Mortality in red pine is low at all spacings because red pine is a poor self-thinner. Red pine trees grow approximately equally in height and no suppression occurs. However, crown size is eventually reduced in the closer spacings and growth will slow.

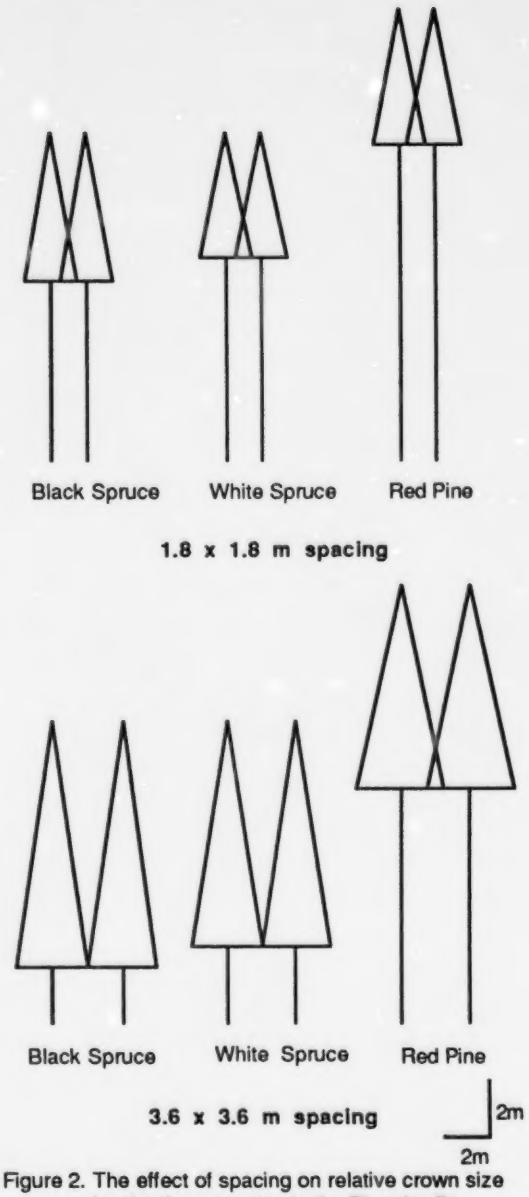

Figure 2. The effect of spacing on relative crown size for the three species in the Thunder Bay Spacing Trial in 1988 (Age 37 years).

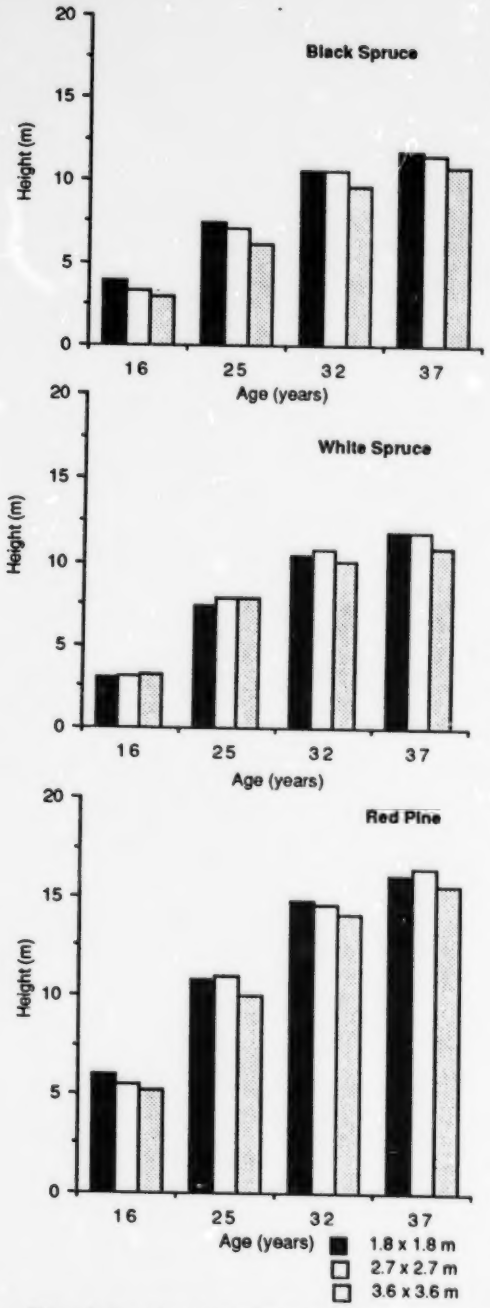

Figure 3. The effect of spacing on the height growth of the species in the Thunder Bay Spacing Trial.

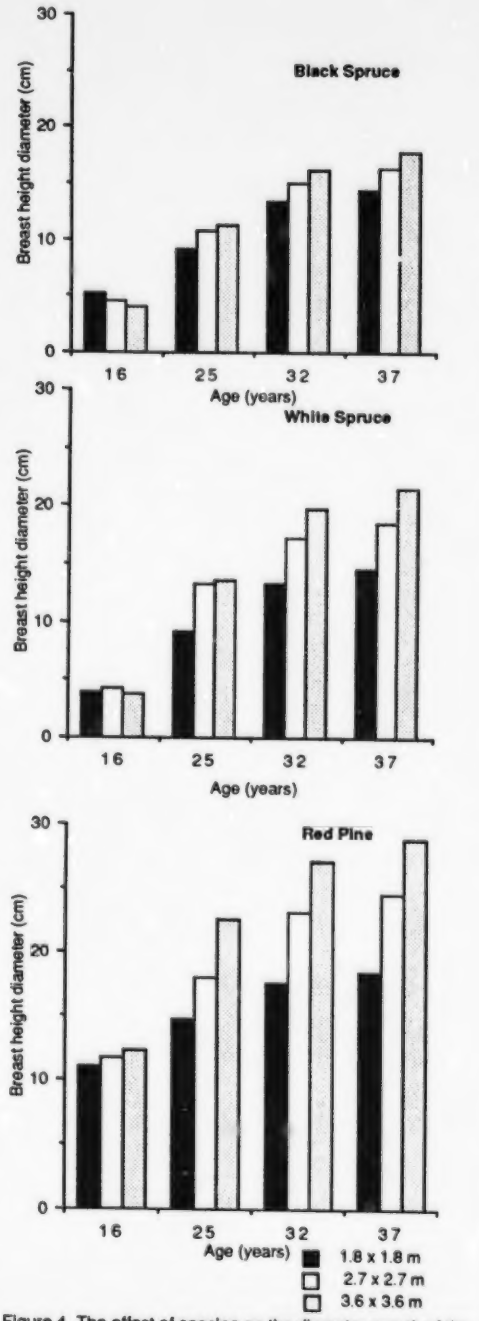

Figure 4. The effect of spacing on the diameter growth of the species in the Thunder Bay Spacing Trial.

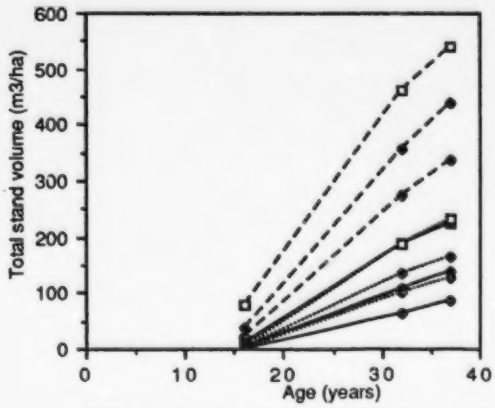

Figure 5. Volume over age for the species in the Thunder Bay Spacing Trial.

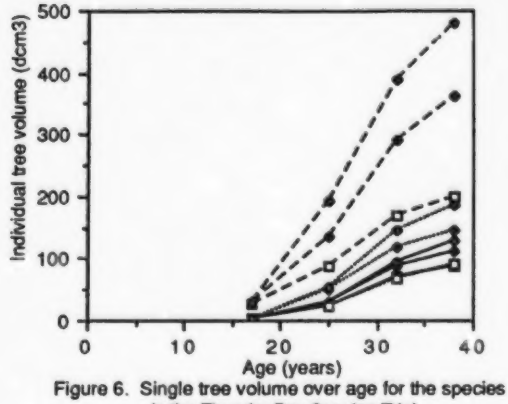

Figure 6. Single tree volume over age for the species in the Thunder Bay Spacing Trial.

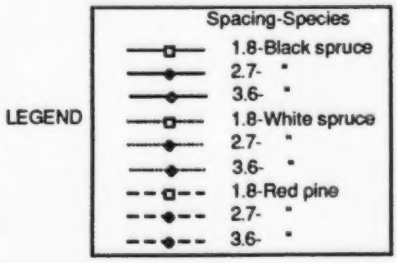

Table 1. Number of trees per hectare and survival (%) for three boreal species at three spacings.

Year (Age)	Species	Spacing (m) 1.8 x 1.8	2.7 x 2.7	3.6 x 3.6
1988 (37)	Black spruce	2578 (88)	1235 (95)	694 (95)
	White spruce	2557 (87)	1136 (87)	694 (95)
	Red pine	2704 (92)	1213 (93)	708 (97)
1983 (32)	Black spruce	2696 (92)	1242 (96)	694 (95)
	White spruce	2784 (95)	1157 (89)	701 (96)
	Red pine	2725 (93)	1222 (94)	708 (97)
1967 (16)	Black spruce	2813 (96)	1261 (97)	701 (96)
	White spruce	2886 (98)	1183 (91)	708 (97)
	Red pine	2813 (96)	1235 (95)	715 (98)
1951 (0)	Planted	2930	1300	730

Management Implications

The best spacing for planting each species, and the products that can be expected when the stands are cut, are estimated to demonstrate how the spacing trial information applies to forest management.

Black spruce is used mainly for pulp and paper; therefore, full utilization of the available growing space and maximum volume production are the primary objectives of management. Slow growth rates and distinctive wood properties make this species an unlikely candidate for other products. Also, diameter growth, which is required for diemension lumber production, is not increased significantly by wider spacing (Figure 4). As thinning is currently not economically feasible for pulpwood crops in northwestern Ontario, an initial spacing that provides adequate growing space until the trees are ready to harvest is necessary. Assuming a 60 year rotation on good to excellent sites, the results from this trial indicate an initial spacing of 2.0 to 2.2 m (2500-2270 trees per ha) is required for black spruce. (Rotation refers to the time between harvests and corresponds to the culmination of maximum annual growth rates.) This is based on not thinning but obtaining good utilization of the site without excess mortality. At 60 years, an average tree would yield two 4.9 m pulpsticks.

White spruce can be used for pulp or sawlogs and responds to the additional growing space provided by wider spacings. Initial spacings of 2.0 to 2.2 m (2500-2270 trees per hectare) with commercial thinning are potential management options for this species. The products which could be harvested from this site include 4.9 m pulpsticks or 2.5 m sawlogs by age 40. By age

50, an average tree would yield a 4.9 m sawlog and a 2.5 m pulpstick.

Red pine is used mainly for poles and sawtimber requiring large diameters and preferably, few knots. As this is a good site for red pine, it quickly achieves full utilization of the site at the close spacing. Crowding and a reduction in crown size causes growth to stop, so wider spacings should be considered for this species. At the present time, an average bole (stem of the tree) would yield a 4.9 m sawlog plus a 2.5 m pulpstick. By age 40, a 4.9 m sawlog and a 4.9 m pulpstick or three 2.5 m sawlogs plus a 2.5 m pulpstick would be available from each tree. The wider spacings are beneficial in this case because they result in larger logs. However, reduced self-pruning will result in more and larger knots at the wider spacings. Branch pruning will be required if sawlogs are the desired product.

The productivity of both red pine and white spruce in this trial are equivalent to that in southern Ontario (Petawawa Spacing Trial) indicating that wood production in northern Ontario can equal that in southern Ontario for these species.The total and merchantable per ha volumes for the three species are given in Table 2. The reduction in total volume at wider spacings is greatest for black spruce (61 per cent) and least for red pine (37 per cent) with white spruce being intermediate (44 per cent). These values are slightly lower for merchantable volume.

Other studies have shown that the discrepancy in volume between the spacings is reduced over the length of the rotation. The trees planted at wide initial spacing will continue to grow at a sustained rate for a longer period of time whereas the trees spaced more closely undergo a gradual reduction in growth. Thinning in the close spacings would maintain higher growth rates and thus increase the total volume produced on a given site during one rotation.

Table 2. Total and merchantable volume (m3 per ha) for three boreal species grown at three spacings.

Year (Age)	Species	Spacing (m) 1.8 x 1.8		2.7 x 2.7		3.6 x 3.6	
		Total	Merch.	Total	Merch.	Total	Merch.
1988	Sb	226.6	193.3	137.7	122.4	88.1	79.6
(37)	Sw	231.2	194.3	164.5	147.7	127.7	117.5
	Pr	540.8	502.4	439.6	419.7	339.0	325.2
1983	Sb	187.4	159.7	109.9	97.4	64.5	58.1
(32)	Sw	189.0	161.2	135.6	123.5	100.8	93.4
	Pr	461.7	432.8	355.0	333.2	273.9	259.1
1967	Sb	12.1	0.0	3.6	0.0	1.4	0.0
(16)	Sw	5.3	0.0	2.7	0.0	1.3	0.0
	Pr	78.0	53.7	36.3	27.3	21.9	17.3

Biological Implications

Tree spacing alters the ecosystem within the stand. Some of the physical factors affected are light transmittance and available soil moisture. These influence the composition and abundance of vegetation which in turn influence wildlife habitat.

Crown closure occurs later in stands with wide initial spacing than stands with close initial spacing. Later crown closure results in increased soil moisture and light at the forest floor. This encourages the growth of shrubs, herbs and grasses which provide forage for wildlife. This is in contrast to the feathermoss mat which accumulates under closed stands.

Later crown closure also results in tree branches touching the ground for a longer period of time. Black spruce stands in areas moist enough to have moss in the understory may layer (branches buried in the moss root and new stems grow) resulting in an uneven-aged stand.

Summary

The importance of initial spacing in stand development and the difference in growth rates and characteristics of the three species are well illustrated by this trial. The information gained from this trial will aid forest managers in establishing the forests of the future.

SELF-GUIDED INTERPRETATIVE TRAIL

This trail with signposts was established with the objective of illustrating the growth and development of boreal species in relation to spacing, and introducing potential management options. Figure 1 shows the layout of the trial, the self-guided trail and the posted stops. The trail allows you to view the effect of the 1.8 and 3.6 m spacings on the development of the three species.

As you walk through the plantations look at the individual stands and note the differences in branch habit, crown size, density, and amount of light penetrating the canopy and how these vary between species and spacings.

CAUTION: Small research studies are in progress throughout the open areas and within the plantations. Your co-operation in leaving these areas undisturbed would be appreciated.

STOP 1. Jack pine - 1.8 x 1.8 m

Jack pine is among the three most important commercial conifer species in northern Ontario. It is used for both pulp and paper and sawtimber. This stand was planted at close spacing but high early mortality has resulted in growth characteristics usually found in jack pine planted at wider spacings. The trees are branchy, possess large open crowns and crooked boles. A fair amount of light penetrates the canopy.

The jack pine in this trial was put in as a border and is presented here merely for comparison. The manner in which the branches grow suggests that this stand may not be typical of jack pine in northwestern Ontario. Other stands are less branchy with straighter boles.

STOP 2. Black spruce - 1.8 x 1.8 m

Black spruce is the most important commercial tree species in northern Ontario and is used mainly for pulp and paper but sometimes for dimension lumber. Note the height and diameter differences between trees within the stand and the number of dead stems. Crowding has caused self-thinning mortality to occur in this stand. The canopy is closed and the crowns are small. The live branches are well away from the ground and the boles are relatively straight. Note the low light levels and the lack of vegetation except for feathermoss under the stand. Feathermoss proliferates after crown closure and provides a nitrogen source for the spruce.

This stand would be used for pulp and so would normally not be thinned. In the event that diemnsion lumber were desired it would have been ready for thinning at age 30 (year 1981). The theoretical rotation

age (the point at which average annual volume increment equals current annual volume increment and the stand is ready for harvesting) would be 38 years (year 1989). However, it would probably not be harvested until age 60 because older trees are larger, have proportionatly less juvenile wood and cost less to harvest. As well, longer rotations prolong the time between regeneration and costs.

STOP 3. White spruce - 1.8 x 1.8 m

White spruce is used for both pulp and paper and dimension lumber. Note the live branches which are well away from the ground, the variability in height and diameter and the number of dead stems. Little or no light penetrates the canopy and no vegetation except feathermoss is growing under the stand.

This stand would have been ready for thinning at age 30 (year 1981). The theoretical rotation age would be 38-39 years (years 1989-90) but the stand would not normally be harvested until age 60 for reasons listed previously.

STOP 4. Black spruce - 3.6 x 3.6 m

Note that the branches reach almost to the ground, they are thicker and more abundant than in the 1.8 m spacing and more light reaches the ground. Vegetation is growing under the stand. Very little mortality is apparent. New trees may begin to develop by layering (branches that touch the ground develop roots and a new stem grows) because of the amount of available light.

The theoretical rotation age for this stand would be 42-43 years (years 1992-93). At its present rate of growth this stand will not reach full occupancy of the site until age 68 (year 2019) and would not require thinning until age 80 (year 2031).

STOP 5. White spruce - 3.6 x 3.6 m

Note that the live branches reach almost to the ground, they are thicker and more abundant than in the 1.8 m spacing and more light reaches the ground. Vegetation below the canopy is well developed. Very little mortality is apparent.

The theoretical time to harvest stand would be age 40 (year 1991). At its present rate of growth this stand will not reach full occupancy of the site until age 83 (year 2034) and would not require thinning until age 100 (year 2051).

STOP 6. Red pine - 1.8 x 1.8 m

Red pine is mainly used for poles and sawtimber. Note the small sparse crowns and the amount of light penetrating the canopy. All trees are approximately the same size and almost no mortality is apparent. There are few small branches which occur high on the bole. Self pruning has occurred over the years.

The theoretical rotation age for this stand would be 38 years (year 1989). It would have been ready for thinning at age 22 (year 1972).

STOP 7. Red pine - 3.6 x 3.6 m

Note that the crowns are much fuller with thicker, more abundant branches and the diameters are much larger than in the 1.8 m spacing. The amount of light penetrating the canopy is not very different from the 1.8 m spacing.

The theoretical rotation age for this stand would be 40 years (year 1991). At its present rate of growth this stand will reach full occupancy of the site at age 40 (year 1991) and would be ready for thinning at age 51 (year 2002). Unless very large logs were desired this stand would probably not be thinned but would be carried to rotation as is.

Stops 8, 9 and 10 are provided for those who are interested.

GLOSSARY OF TERMS

bole - the stem of a tree

canopy - formed by a group of adjacent tree crowns

crown closure - occurs when branches of adjacent trees touch

juvenile wood - wood formed in the first five to fifteen growth rings from the center of tree - not as strong as mature wood

rotation age - time from regeneration to harvest

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